WISCONSIN ENDANGERED RESOURCES REPORT # 112

Guidelines for Carnivore track Surveys During Winter in Wisconsin

By: Adrian P. Wydeven, Ronald N. Schultz, and Rebecca A. Megown

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SUMMARY

Guidelines were developed for conducting winter track surveys for medium and large carnivores for heavily forested areas of northern and central Wisconsin. Tracking guidelines were especially focused on timber wolves but also were directed at other medium and large carnivores possible found in Wisconsin (ie. coyote, foxes, dog, cat, bobcat, puma, lynx, fisher, otter, badger, skunk, wolverine, raccoon, and bear). Northern and central Wisconsin were subdivided into 123 survey blocks that averaged 193 mi^2 (range 20-548 mi^2). Surveyors were to be assigned to individual survey blocks and were requested to do 3 or more good surveys totalling 60-100 miles (by vehicle or on foot) per survey block. The general instructions and equipment necessary for doing surveys are listed. These guidelines were especially designed for volunteers assisting DNR in surveying forest carnivores.

BUREAU OF ENDANGERED RESOURCES
Wisconsin Department of Natural Resources
P.O. Box 7921
Madison, WI 53707
608/266-7012
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GUIDELINES FOR CARNIVORE TRACK SURVEYS DURING WINTER IN WISCONSIN

BY ADRIAN P. WYDEVEN, RONALD N. SCHULTZ, AND REBECCA A. MEGOWN

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INTRODUCTION:

Welcome to Wisconsin's carnivore tracking program! These guidelines will explain how to conduct track surveys, as well as explain the background of track identification and track surveys. The guide is not intended for identification of individual species, but we will list references that will help you with species identification.

Although the impetus for the carnivore track surveys is to get better information on wolf populations, we also want to use these surveys to get better information on other carnivores. Therefore, we will collect information on all medium or large carnivores (including: coyotes, foxes (red and gray), free-roaming domestic dogs, bobcat, puma (cougar), lynx, free-roaming domestic cats, fisher, otter, badger, skunk, raccoon, and bear). Several of these carnivores will not be very active in mid-winter, but may be detected in early or late winter track surveys (i.e. badger, skunk, raccoon, and bear).

The main goals for the carnivore track surveys are as follows:

1. Determine wolf numbers, distribution, breeding status, and identification of specific packs.
2. Develop an index to abundance and distribution of other medium-sized and large carnivores in Wisconsin.
3. Determine possible existence, and locations of rare carnivores such as Canada lynx, puma, and perhaps wolverine.

BACKGROUND:

Most carnivores are classified as predators, and until recent years have often been viewed negatively by much of the public. Many of these carnivores were harvested extensively for fur in the past, but fur harvests have declined in recent years. The development of environmental ethics in the middle of this century have increased public perception of the value of predators to ecosystems. Recent concerns over biodiversity have identified conservation of carnivores as an important issue in the protection of biological diversity.

Because many carnivores are very secretive and occupy very large home ranges, attempts to survey populations have been problematic. Development of radio-telemetry has improved our ability to assess carnivore populations for localized areas (Mech 1974). Although radio-telemetry can provide very accurate information for specific areas, interpolation on regional-wide or state-wide bases is much less precise. The extent through which radio-telemetry can be used over large areas is restricted by costs and manpower. Population modeling can be done on harvested carnivores that are registered and have biological specimens collected, but modeling efforts are most useful if they can be compared to other independent surveys (Berg and Kuehn 1994).

Wisconsin wildlife managers began conducting track surveys for furbearers in 1977 and during most winters conduct two 10-mile survey routes in 17-18 northern Wisconsin counties (Dhuey 1995). Formal track surveys by the Wisconsin DNR on wolves began in 1979 as part of the state wolf monitoring program along with radio-telemetry and howling surveys (Wydeven et al. 1995). Volunteer track surveys on Wisconsin wolf packs began in 1977 (Thiel and Welch 1981), and was used by Thiel (1978) to search for wolves in northern Wisconsin in 1974 to 1975. In recent years, over 3000 miles of wolf track surveys were conducted each winter (Wydeven and Megown 1995). Surveys on American martens have been conducted in Wisconsin since 1981 (Kohn and Eckstein 1987); these surveys also collect information on other carnivores, and in recent years have covered about 120-320 miles in Wisconsin (Wydeven and Ashbrenner 1995).

Despite these extensive track surveys conducted each year, the need for additional survey information does exist. Wolf surveys as conducted by DNR are relatively expensive and may be difficult to maintain at present levels when wolves are down-listed. Also, as wolves expand into new areas, it will become difficult to maintain adequate information on new areas.

Additional information is also needed on other carnivores. Year to year fluctuations on regional or local basis are difficult to detect with present survey efforts. Overall distribution and abundance are not accurately defined at present. Although DNR receives 40-50 reports of cougar observations each year, it is still not clear if a wild, free-roaming cougar population exists in the state (Wydeven 1995). More track surveyors would benefit these efforts to provide better conservation of carnivores in Wisconsin.

IDENTIFICATION OF CARNIVORE TRACKS:

We will not attempt in these guidelines to duplicate the numerous guides that already exists for track identification, but do want to discuss a few hints to assist identification.

Our emphasis on surveys will be mainly to record the medium and large carnivores. If we recorded all mammals, it would be difficult to adequately survey the extensive areas used by large carnivores. Yet it is important to be aware of these other mammal tracks to differentiate them from the carnivores. Therefore, it is important to be familiar with all mammal tracks that could occur in an area. We are not including martens and mink as target survey species because adequate survey for these species would require careful examination of most hare and squirrel tracks detected on the survey; this would reduce your ability to adequately survey a large block of land. Although marten and mink are not target species, if tracks of these species are identified, they should be recorded.

The tracking guide we most prefer for use in track surveys is Halfpenny (1986) "A Field Guide to Mammal Tracking in North America". This guide provides good explanations of measurements, gait patterns, and species track identification. Track drawings are somewhat stylistic, but adequately portray track appearance. The guide is especially good in providing excellent photos of scats. Halfpenny's book is probably one of the most scientifically based tracking guide on the market today.

Two other good guides are Murie (1954) "A Field Guide to Animal Tracks" (Peterson Field Guide), and Rezendes (1992) "Tracking and the Art of Seeing: How to Read Animal Tracks and Sign". Murie is the old standard for most trackers and it still is a good guide. Rezendes has excellent photos of animal tracks and other sign, but some of his information is inaccurate or out dated. Rezendes does provide excellent information on tracks and sign of eastern coyotes.

A popular track guide that we do not recommend is "Tom Brown's Field Guide to Nature Observation and Tracking" (1983). This guide is very philosophical and mystical, but not very accurate. The illustrations of animal tracks are very poor, and a lot of information is inaccurate. Brown states incorrectly that the fox is the only canid that shows direct registration when walking; all wild canids show direct registration, only domestic dogs are the exception.

Tracks should generally be identified by careful examination and measurement. The first time a species is encountered it would be useful to take careful measurements. The standard measurements we would like to see follow Halfpenny (1986, pp 12-14); these are also illustrated on Appendix 1.

Stride measurements is the distance from one footprint of the same foot to the next place the same foot appears; it should be measured from heel to heel. Length of tracks is measured from the back of the heel to the longest toe, and should not include the claws. A form showing the type of measurements to record is shown in Appendix 2. It is important to use consistent measurements. Track books have varying descriptions of length measurements (with or without claws) and stride measurements.

Generally several tracks need to be observed before a species can be identified. Along with the tracks, gait patterns should also be carefully examined. Tracks and patterns will vary with different types of snow conditions. Often when snow is very fluffy, it will be necessary to follow tracks into adjacent forest areas to find tracks in more dense, shallow snow, especially under conifers. Whenever identification of tracks are questionable, photos with a 6 inch ruler laid next to the track, (with visible numbers) should be photographed from directly above for later examination.

Three species that especially give surveyors problems in track identification are wolves, cougars and martens.

Wolf tracks have the appearance of large dog-like tracks with front feet length at least 3.5 inches (9.0 cm) and hind feet length usually at least 3.1 inches (8.0 cm). The feet generally have a more robust appearance than dogs of similar size. Wolves have walking patterns where by the hind foot often directly registers over the front print; domestic dogs usually don't follow this pattern with hind foot stepping to the side of the front print. Dogs often follow irregular travel patterns while wolves tend to walk straight down a road or trail unless they are moving to the road shoulder for scent marking. Dog sign often will be associated with human sign, and are often close to residence, but occasionally will occur by themselves miles from any house.

Wolves can be separated from coyotes be larger sized tracks and greater stride length. Coyote front tracks are usually 2.8 inches (7.0 cm) in length of less and are more narrow than wolves. Walking wolf strides are 33-40 inches (84-100 cm) while coyotes are 25-30 inches (64-76 cm).

The form developed by James Halfpenny and based on an article by Harris and Ream (1983) can be used to do discriminant analysis on wolf tracks (Appendix 3). Although discriminant analysis initially may seem somewhat overwhelming, the system is not overly complicated. We have used this form for analyzing wolf tracks in Wisconsin from photos and plaster casts, and find it relatively reliable. The analysis consists of a variety of ratios of track measurements that are compared to 6 common dog breeds. If in all the analyses, the animal measures more wolf-like than dog-like, one can be relatively sure you have a wolf track. Often comparisons need to be made only on the first 3 dog breeds to determine if the track is of a dog or wolf. The measurements do not need to be made in the field, and can be obtained from good quality photos taken with a ruler in them. Because ratios are used for separating wolf from dog, the actual measurements can be done from photos, and either metric or inches can be used for measuring.

Observations of cougar and cougar tracks are frequently reported to the DNR. All reported cougar tracks (field observation, plaster casts, and photos) observed by us have been of other species including dog, bear, fisher, lynx, and bobcat. Large dog tracks are probably most frequently confused with cougar tracks. Smallwood and Fitzhugh (1989) provide a key for separating cougar from dog tracks (Appendix 4). Major features of cougar tracks are lack of claws (or rarely narrow knifelike claw marks), rear heel pad with 3 similar size lobes, and front of heel pad square or concaved. If tracks are found that are thought to likely be cougar, contact one of us as soon as possible.

Although marten are not target species for the survey, trackers should be familiar with them because of possible confusion with fisher. The problem with marten and fisher is that they have very similar tracks that overlap in size. Zielinski and Truex (1995) analyzed patterns of tracks from fisher and marten on sooted aluminum plates. They developed some detailed measurements for separating the two species. In their measure of western marten and Great Lakes fisher, the study found that greater than 95% of fisher forefeet were 42 mm or longer and 37 mm wide or greater. Marten tracks included more than 95% with less than 40 mm in length and less than 37 mm wide. It's not clear how accurately these could be measured in snow, but careful measurements might suggest that length of 1.6 inches (41 mm) by 1.5 inches (38 mm) width would be the cut off points between fisher and marten if measurements are made at the bottom of a track. Any marten tracks identified on surveys should be recorded on the data sheet.

The first time a rare species is encountered (i.e. wolf, cougar, Canada lynx), an observation card should be filled out and sent to the DNR station in Park Falls so that the occurrence can be verified. Also, a mark of the location where the animal was observed should be made on the appropriate map.

TRACKING SURVEY BLOCKS:

Portions of northern Wisconsin and central Wisconsin were subdivided into tracking survey blocks. The survey blocks ranged from 74 to 1419 square kilometers (29 to 548 square miles)and average 501 square kilometers (193 square miles) (Figure 1). Carnivore survey blocks are normally bounded by paved roads, large bodies of water, or other distinct boundaries. In a few cases where large areas exist with no paved roads or other distinct boundaries, gravel or dirt roads would be used for boundaries.

The intent of this size and configuration of survey units is as follows:

- to cover an area the size of 1 or 2 wolf territories
- to designate an area that can usually be adequately covered in a day's survey
- to use boundaries that can easily be identified in the field
- to designate an area with boundaries over which wolf territories would not normally overlap [wolf territories in Wisconsin usually do not extend over paved highways(Mladenoff et al 1995)]

In winter 1992-1993 we examined the ability of 2 experienced trackers in detecting total number of wolves in known territories. In 9 territories it took the trackers on the average 2.1 visits (range 1-3), 60 miles (range 8-148), and 10.4 hours (range 4.0-23.0) to determine the number of wolves in the territory. In four of these territories the wolf numbers were verified by aerial radio-telemetry, and in the other 5 territories wolf numbers did not change after additional surveys. Therefore the wolf count detected in each territory was a reasonable estimate of the minimum wolf numbers present in the territory.

Based on this analysis, we would like 20-30 miles examined on each survey block on each visit. The survey should take 5-8 hours in each block. At least 3 good surveys should be done over the winter, covering 60-100 miles. Most of these miles should consist of driving snow covered roads, but may also include: walking, snowshoeing, skiing, and snowmobiling.

CONDUCTING THE SURVEY:

Surveys should normally be run 1 to 3 days after fresh snow falls. If run earlier, there often will not be enough time for adequate tracks to accumulate. If run much later, vehicle traffic or snow plowing may have obliterated most tracks, or new and old tracks will have overlapped, so that getting counts will be difficult.

On each survey, attempts should be made to cover as many miles of snow covered roads as possible. The surveyors should try to get good coverage throughout most of the block. Most Wisconsin wolf packs overlap numerous dirt roads, and during winter will readily travel along snow covered roads. In some blocks there may be some large areas that can't be driven; if possible these areas should be covered by snowshoeing or skiing. Snowmobiles should only be used along designated trails.

The intent of the survey is not to follow any exact route, but to cover enough of a survey block to detect wolf presence. Once wolf tracks are encountered, they should be back-tracked to where they first entered the road and should be followed until they leave the driveable road. If you follow wolf tracks into an adjacent survey block, start a new data sheet. Whenever possible tracks may be followed for up to ½ mile from roads to get better counts, and determine general direction of travel. If several different sets of wolf tracks are observed in different locations, attempts should be made to see if new sightings are related to previous observations. Wolves can travel 30 miles in their territories within a day's time. Within 2-3 days, wolves could be expected to occur anywhere within the territory.

Care should be made to avoid over counting. Wolves occasionally will loop around and follow portions of a route more than once. A set of 4 tracks could be 2 wolves that looped around and followed the same route twice since the last snow fall. Thorough backtracking and forward tracking should be able to separate these. Special care should be made at getting counts near kills because wolves may approach from the same way and leave by a second route. Wolves will frequently return to a carcass, and abundant tracks near carcasses may be deceiving.

Wolves often will walk single file in deep snow, and sometimes you may need to follow these for several miles before getting a good count. The wolves may eventually spread out on beaver ponds, under dense conifer cover, or when they move onto a road with light snow cover.

Attempts should be made to get a total wolf count for survey block on each trip. See the example of the data sheet in Appendix 5 to determine how to record the data. At the end of winter a summary sheet should be filled out and sent to the DNR office in Park Falls (Appendix 6).

All wolf raised-leg urinations (RLU) and squat urinations (SQU) should be recorded, because they are important in determining territorial behavior of wolves (Rothman and Mech 1979). Also estrus blood in urine should be recorded.

Other medium or large carnivores should be recorded whenever their tracks are encountered. If a specific species crosses the road several times, all counts within 0.3 mils of each other should be recorded as 1 animal. If a carnivore walks down the road, which is especially common for the canids, indicate the first and last odometer reading, and draw an arrow in the direction of travel.

Any carcasses of predator killed animals should be recorded on data sheets. If possible, determine the predator involved, as well as age, sex and physical condition of the kill. Also record carcasses scavenged by carnivores.

Because paved roads and highways will be used as boundaries on survey blocks, these units often will contain some areas that are not suitable habitat for wolves and forest carnivores. Surveyors will need to get to know their survey blocks well, and concentrate their efforts on the most suitable habitat. Areas of extensive farmland and residential areas should be avoided. Areas of suitable habitat for wolves and forest carnivores will include some the following characteristics:

- low density of driveable roads (<1 mile of road/mi^2 of land)
- low density of people (<10 people/mi^2)
- most of the habitat is forest or other native vegetation including bogs, barrens, and openings (>90% forest and other native vegetation)
- lack of agricultural land or urban areas
    - less than 10% agricultural land
    - more than 1 mile from urban areas
- low percentage of lakes in area (<2% lakes)

These characteristics of wolf habitat in Wisconsin are discussed in Mladenoff et al (1995).

TRACKING TOOLS:

Tracking does not require many specialized tools, but a few items should be carried by all surveyors. Detailed maps of the survey area is especially important. It is highly recommended that surveyors obtain copies of the DeLorme "Wisconsin Atlas and Gazetteer". This book has detailed maps of all of Wisconsin at a scale of 1:150,000. The atlas is available in many book stores and sporting good stores around the state. Detailed topographic maps can also be obtained from the Wisconsin Geological and Natural History Survey (Madison, WI 53706). The 1:100,000 scale regional maps or county maps are especially useful, but the 1:24,000 scale generally covers too small an area to be used for most survey blocks. Forest Service maps of the Nicolet and Chequamegon National Forests are also very useful maps and can be obtained from the headquarters in Rhinelander and Park Falls, as well as district offices in Glidden, Medford, Hayward, Washburn, Mountain, Laona, Eagle River, and Florence. Many counties also have detailed maps available through the local Chamber of Commerce or County Forestry offices.

Tools that all surveyors should carry includes the following:

- compass
- 6 inch ruler in inches and mm
- tape measure (inches and mm if possible)
- detailed map at scale 1:150,000 or greater
- 35 mm camera
- field guide
- data sheets and clipboard
- notebook and pencils
- watch
- flashlight
- survey forms (Appendix 2 and 5)

Optional equipment could include the following:

- plaster of paris and mixing cups
- snow print wax
- pedometer for determining mileage when walking
- skies or snowshoes
- plexi-glass to trace outline of tracks
- geographic positioning system unit

•shovel/tire chains

TRACKING ETHICS AND CAUTIONS:

Some ethical considerations and precautions need to be followed when conducting tracking surveys in north and central Wisconsin.

- Park vehicles on the side of roads in safe location, but be careful to avoid getting stuck in snow covered ditches.
- When driving slowly, be especially alert for logging trucks.
- Don't follow back roads with deep snow cover, and generally only do surveys with four-wheel drive trucks.
- Don't follow wolf tracks for long distances off roads in March and April when wolves are starting to use dens, to avoid disturbing wolves or causing abandonment of den sites.
- Avoid disturbing tracks if possible; others may also being doing surveys, and tracks are usually the closest people will get to enjoying these carnivores in the wild.
- Don't follow carnivore tracks onto posted private land.
- Don't attempt to howl at wolves on the tracking survey; if you would like to conduct howling surveys please contact us for additional guidelines.

FORMS:

Several forms and articles used for tracks surveys are illustrated in the Appendix. Appendix 1 illustrates the types of measure that can be made on tracks. Appendix 2 illustrates a form for recording track observations of individual species; this form should be especially used for unknown mammals or rare mammals. Appendix 3a and 3b shows the discriminant analysis system for separating wolf tracks from dog tracks. Appendix 4 shows a key for separation dog tracks from cougar tracks. Appendix 5 illustrates an example of the data sheet to be used for carnivore track surveys and contains instructions on filling out the form. Appendix 6 is a summary sheet that should be filled out at the end of each tracking season.

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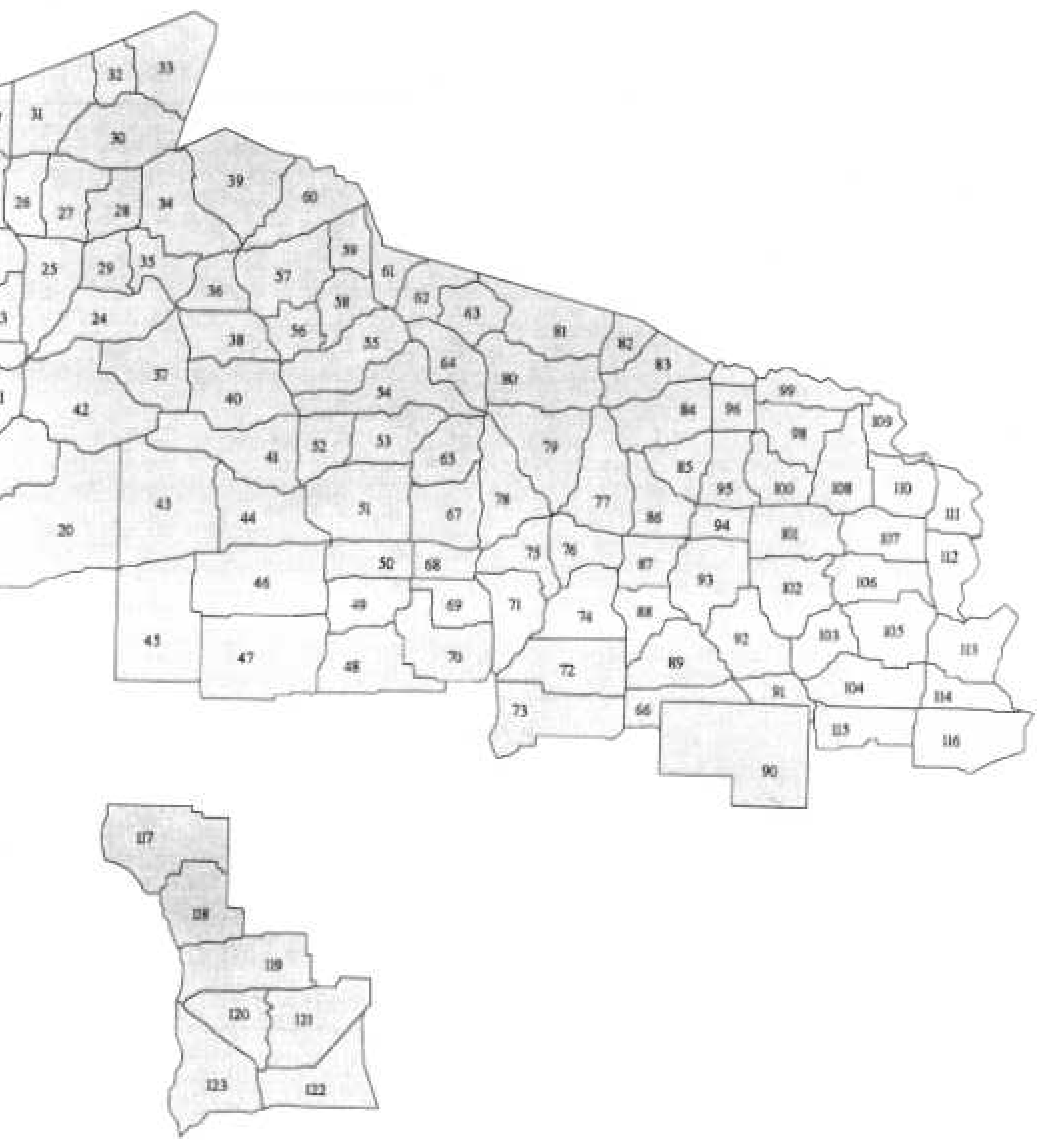
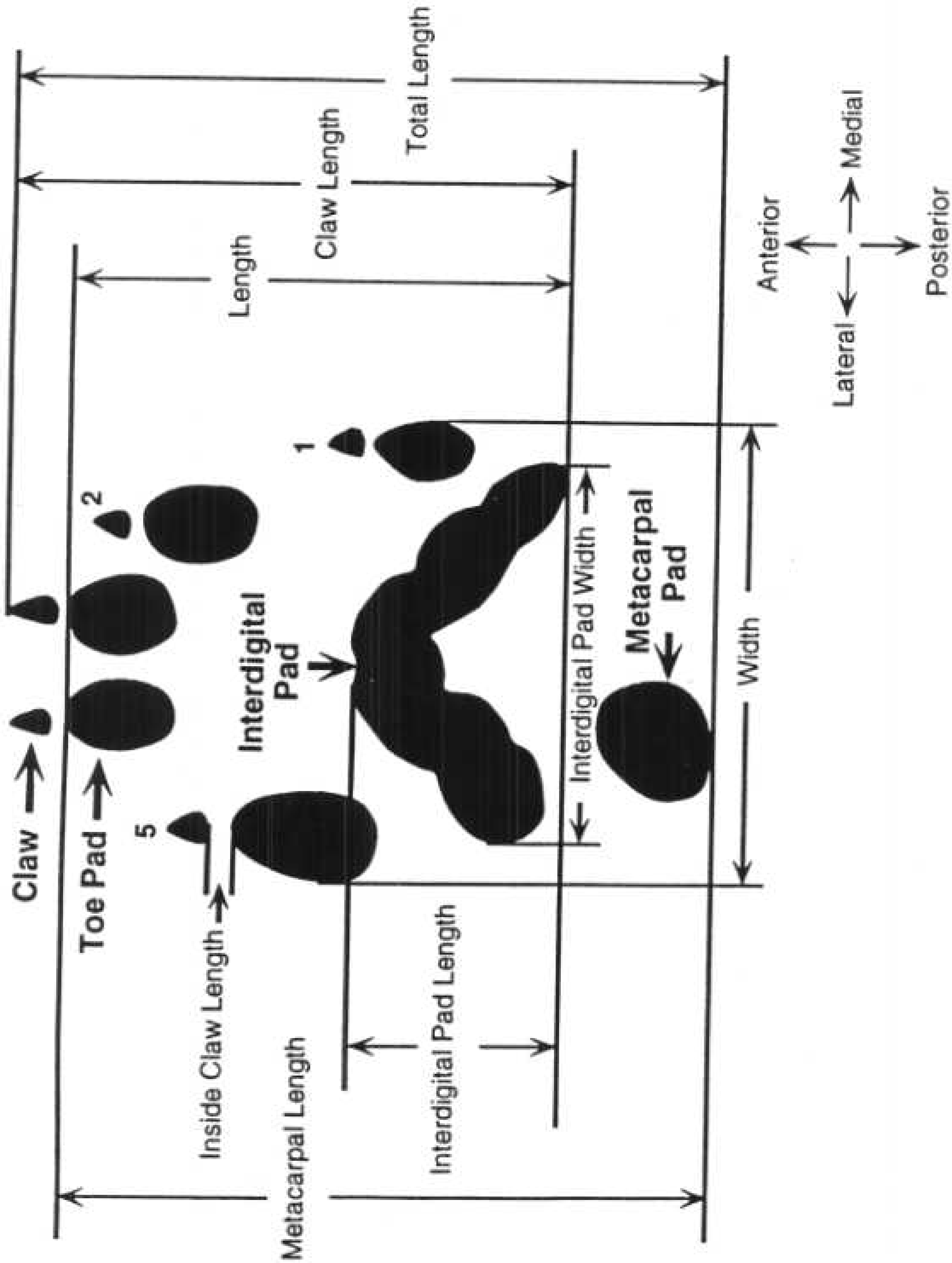
sin wolf survey blocks.

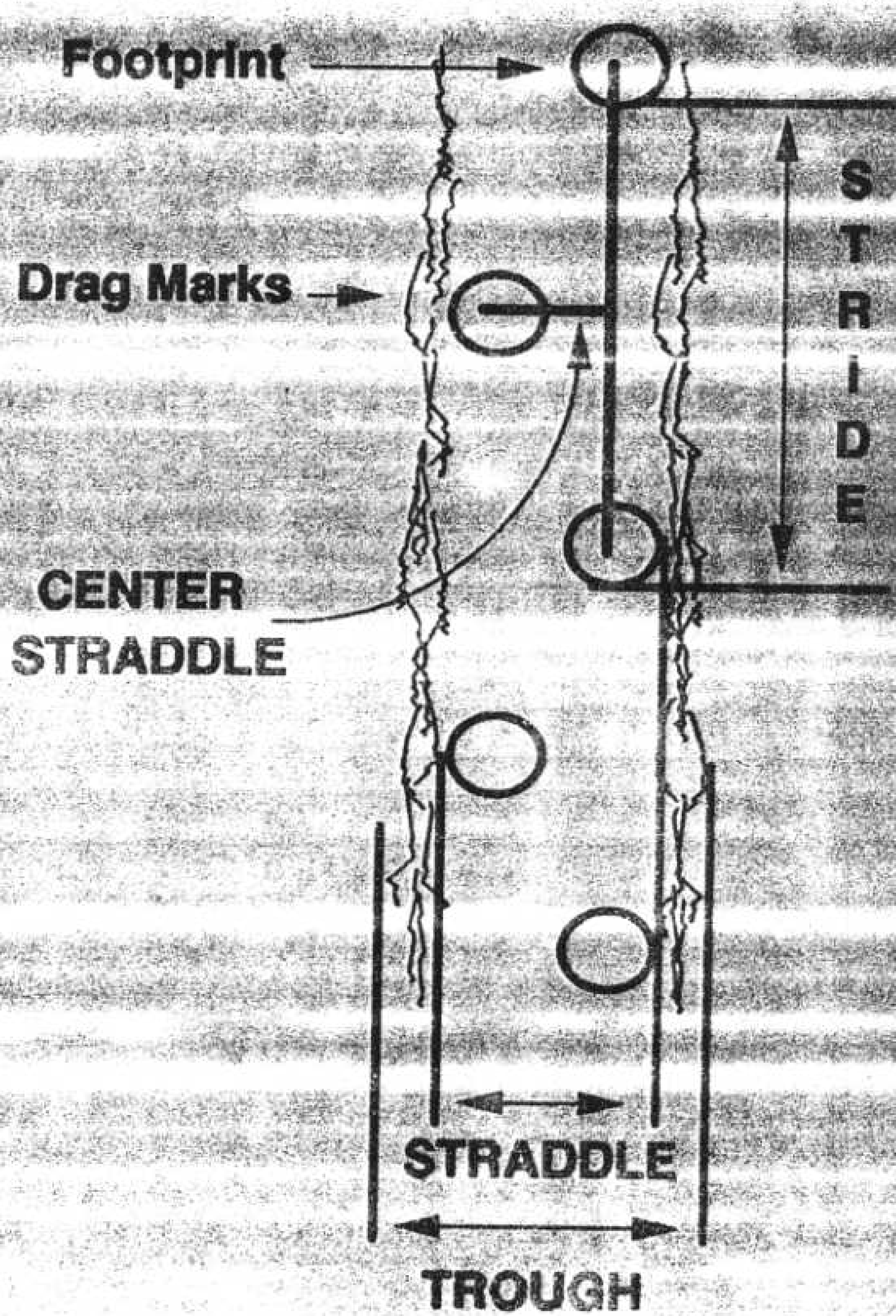


Appendix 1



Total Length
Claw Length
Length
Anterior
Medial
Lateral
Posterior
1
2
3
4
5
Claw
Toe Pad
Inside Claw Length
Interdigital Pad
Metacarpal Pad
Interdigital Pad Width
Width
Interdigital Pad Length
Metacarpal Length

Trail Measurements



Appendix 2

Track Observation Form

Species Observed________________________________ Number observed__________

Date ________________ Time ______ Observers ______________________

Location ____

Legal Description (fill out in the laboratory) : Section ________ Township ___________

Range _________________ Meridian ______________________________

Habitat ____

Elevation ______________ Topography ______________________________

Tracking Surface ____

Measurements units are **cm** or **in** (mark out the units **NOT** used)
M1, M2, M3 refer to sequential measurements on one trail, i.e. 3 strides or 3 right front prints

Gait	**M1**	**M2**	**M3**	**Mean**	**STD**
Stride					
Group					
Straddle					
Center Straddle					
Trough					

Photograph Record		
Film and ASA	Roll Number	Frames

	Length					**Width**				
Prints	**M1**	**M2**	**M3**	**Mean**	**STD**	**M1**	**M2**	**M3**	**Mean**	**STD**
Front										
Hind										
Metatarsal										

Comments and Drawings (make drawings on the back of this form)

Appendix 3a

Discriminant analysis of suspected wolf tracks

Compiled by =

Sample =

Date =

DECISION SCALES

Measurements		Value
A	Claw Length	
B	Total Length	
C	Pad Width	
D	Total Width	
E	Pad Length	
F	Gap Length	
G	Toe Length	
H	Toe Width	
I	Inner Toe Width	
J	Outer Claw Width	
K	Inner Claw Width	

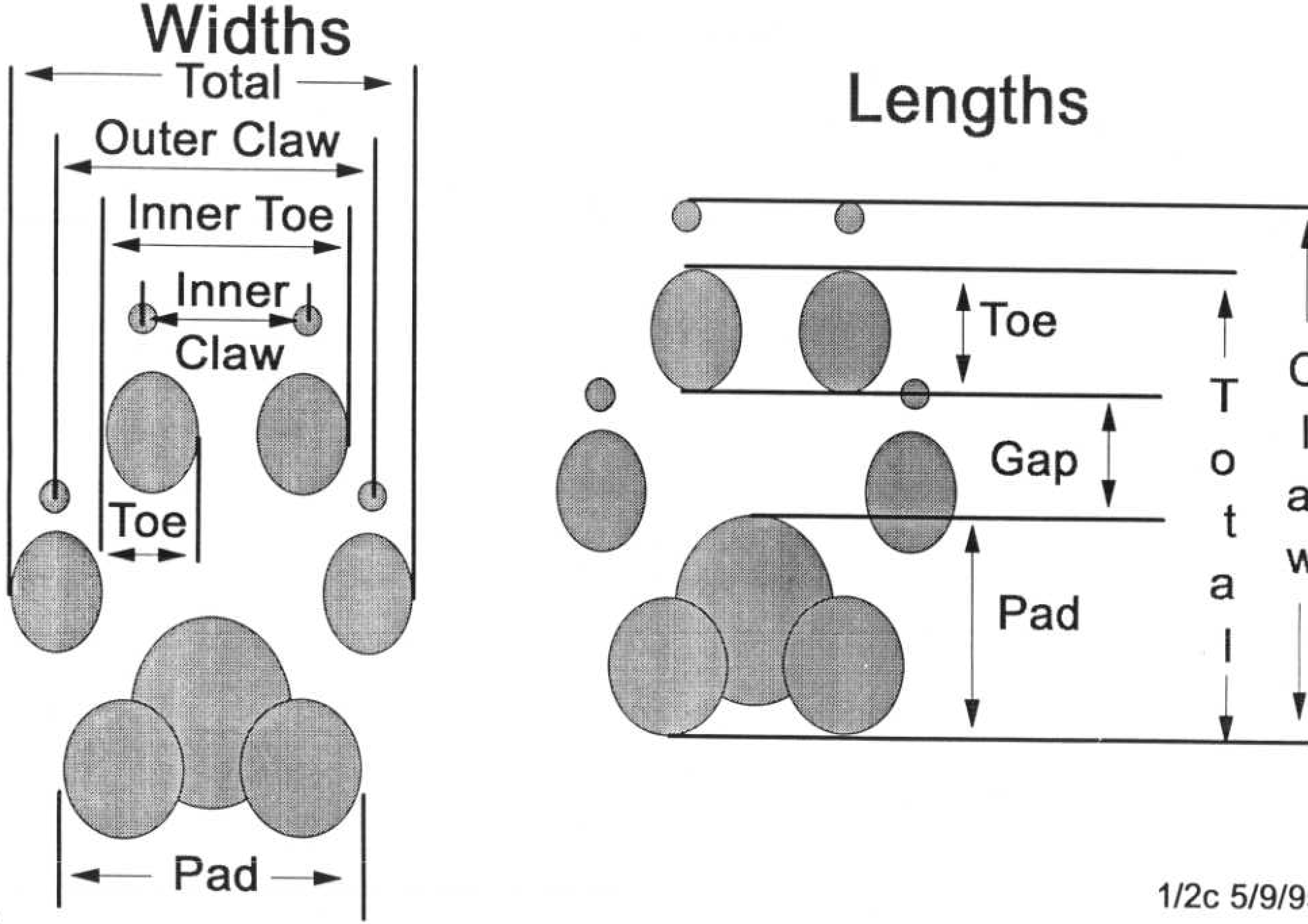
Shape Ratios		Value
1	E/A	
2	E/C	
3	C/J	
4	J/D	
5	K/I	
6	F/B	
7	(G*H)/(E*C)	

	RATIO x		COEFFICIENT =	TEST	Dog	Midpoint	Wolf
GERMAN SHEPARD							
2) E/C		X	0.17551 =		0.22332	0.27263	0.32195
3) C/J		X	0.37572 =				
6) F/B		X	-0.48173 =				
			TEST =				
ALASKAN MALAMUTE							
2) E/C		X	0.23093 =		-0.11815	-0.10437	-0.09059
4) J/D		X	-0.28943 =				
5) K/I		X	-0.03815 =				
			TEST =				
BLOODHOUNDS							
2) E/C		X	-0.06426 =		-0.35131	-0.31908	-0.28686
6) F/B		X	-0.65239 =				
7) G*H/E*C		X	-0.39768 =				
			TEST =				
IRISH WOLFHOUND							
2) E/C		X	0.46767 =		0.16786	0.29513	0.42240
5) K/I		X	0.68867 =				
7) G*H/E*C		X	-0.98935 =				
			TEST =				
GREAT DANES							
1) E/A		X	0.17450 =		-0.30581	-0.23068	-0.15555
2) E/C		X	0.11753 =				
7) G*H/E*C		X	-1.07333 =				
			TEST =				
ST. BERNARDS							
1) E/A		X	1.62743 =		-0.12969	0.00458	0.13886
2) E/C		X	-0.15743 =				
7) G*H/E*C		X	-1.35790 =				
			TEST =				

CONCLUSION =

Harris, R.B. and R.R. Ream. 1983. A method to aid in discrimination of tracks from wolves and dogs. In Carbyn, L.N. (ed). Wolves in Canada and Alaska. Canadian Wildlife Service Report Series # 45.

Appendix 3b



1/2c 5/9/95

Appendix 4a

Differentiating Mountain Lion and Dog Tracks

K. Shawn Smallwood
E. Lee Fitzhugh
Wildlife Extension
Department of Wildlife and Fisheries Biology
University of California
Davis, California

INTRODUCTION

Mountain lions (*Felis concolor*) are cryptic and occur sparsely, so sportsmen, managers, and researchers use their tracks to determine presence and relative abundance (Fitzhugh and Gorenzel 1985, Kutilek et al. 1983, Shaw et al. 1988). Yet, many people, including trained wildlife biologists, have difficulty differentiating between lion and dog tracks (Belden, 1978). This is perfectly understandable as dog tracks vary greatly in shape and size and many are similar to lion tracks. In California, at least 9.5% of volunteers conducting a statewide track survey could not tell them apart (Smallwood and Fitzhugh, unpublished data), even though most volunteer teams included a wildlife biologist. Thus, people often question the use of tracks in mountain lion research and management. Tracking can be an important and inexpensive tool for lion study, but it must be used accurately. This paper examines currently used dog and lion track discriminators, compares them to our observations from the field, and presents the first effort to apply multivariate techniques to distinguish lion from dog tracks. This paper is relevant only for tracks from dust or firm mud because we have little experience with tracking in snow and we have observed serious track distortion in soft mud. The result is a reliable field key and office procedure.

Possible Causes for Misidentification

Illustrative and descriptive errors depicting mountain lion tracks in publications may contribute to misidentifications. A few track traits we observed in the field are consistently misrepresented in publications (except Belden 1978, Downing 1979, and Downing and Fifield 1986). Our field experience was in California, but lions from other states may differ genetically and morphologically and thus leave tracks that look different. However, the same method we used for differentiation can be applied elsewhere to overcome possible geographical variations.

Current Techniques Used for Lion and Dog Track Discrimination

Current literature includes the following differentiators between lion and dog tracks:

1. The presence of claw marks in the tracks of dogs and their absence in the tracks of lions (Murie 1974; Belden 1978; C. B. Koford, unpubl. manuscript).
2. The presence of 3 heel lobes on the tracks of lions and their absence on dogs (Belden 1978; Shaw 1983; C. B. Koford, unpubl. manuscript).
3. The overall elongate shape of dog tracks vs. the round shape of lion tracks (Belden 1978; Shaw 1983; C. B. Koford, unpubl. manuscript).
4. The asymmetry of the lion's toes around the heel pad, including a leading toe, vs. the symmetry of the dog's toes (Belden 1978; Downing and Fifield 1986; C. B. Koford, unpubl. manuscript).
5. The squared front of the lion's heel pad vs. the more rounded and pointed front of the dog's heel pad (Downing and Fifield 1986; C. B. Koford, unpubl. manuscript).
6. The pointedness of the lion's toes vs. the blunt shapes of the dog's toes (Downing and Fifield 1986, C. B. Koford, unpubl. manuscript).
7. The occurance of single, evenly-spaced tracks of dogs vs. the occurance of pairs of tracks, usually one on top of the other for lions (Murie 1974, Shaw 1983). The placement of the tracks with respect to each other is referred to as the track pattern.
8. The larger size of the lion's heel pad relative to the whole track compared to the dog's (Murie 1974; Shaw 1978; and C. B. Koford, unpubl. manuscript).
9. The smaller ratio of the widths of the widest toe to the heel pad for lions. Belden (1978) suggested that when the ratio exceeds 0.44 the track was made by a dog, and below 0.44 the track was made by a lion.

ed. R. H. Smith 1988

Prescott, Arizona

10. The smaller distance between the dog's toes than between the lion's toes (Downing and Fifield 1986).

Almost all of the traits presented above can be used some or most of the time, but enough exceptions exist to warrant further analysis. Our paper is divided into three parts: Part 1, a list and discussion of the reliability of the traits presented in the literature, based on our observations from considerable field work plus some additional traits we found to help discrimination; Part 2, a multivariate analysis of traits we believe discriminate well; and Part 3, presentation of a dog/lion track classification key that uses the most accurate and easiest-to-apply discriminators from Parts I and II.

Part 1: The Reliability of Track Traits Used to Discriminate Lions from Dogs

Methods.

We applied the traits presented in the literature as discriminators between lion and dog tracks to tracks we collected during our previous 5 years of field work. We evaluated the reliability of each of these traits in the order they were presented in the Introduction, as well as for three other traits that we felt might be useful.

Results.

1. We never saw a lion track that included claw marks but we were told by professional trackers that they occur, and some authors have recorded their occurrence (Downing 1979, Shaw 1983). We did encounter dog tracks that had no claw marks, including tracks from 2 of the 19 dogs in our quantitative analysis. Those who have observed claw marks in lion tracks reported that they were much thinner than claw marks in dog tracks. Therefore, the presence or absence of claw marks and their relative widths in a track is an excellent discriminator, but not a perfect one.

2. Most dog tracks only showed 2 heel lobes. However, we encountered a fair number of dog tracks that included 3 heel lobes, and most dogs we examined had 3 lobes on their feet. This suggests that dogs walk more on their toes than lions so that relatively less weight is applied to the rear of the foot. However, when dog tracks included 3 heel lobes, they still differed from the 3 heel lobes of lions most of the time: the 2 outer heel lobes in dog tracks were smaller relative to the middle lobe (Figure 1), whereas mountain lion heel lobes were more equal in size and shape. Therefore, the number of heel lobes and their shapes can greatly increase our ability to discriminate dog and lion tracks, but again, not all of the time.

3. Not all dog tracks were relatively elongate and not all lion tracks were relatively round. However, both lion and dog tracks tended to follow a similar pattern of shape--the rear tracks usually were more elongate than the front ones. Thus, the overall elongate shape of a dog or lion track was a poor trait for discrimination.

4. Lion tracks usually included a leading toe. The second toe from the medial aspect of the track leads the third, and the first toe also usually leads the fourth. However, some lion tracks we found were nearly symmetrical, and a few dog tracks had leading toe prints similar to the lion's. Therefore, this trait should not be considered alone when differentiating dog and lion tracks.

5. We found no dog tracks that were squared off at the front of the heel pad as in lion tracks. However, some rear tracks of lions failed to show the squared front of the heel pad and appeared pointed very much like dog tracks. This probably results when the front of the lion's heel pad fails to press firmly into the soil. This trait, therefore, should discriminate well except when only rear tracks are visible in a track set.

6. We found that lion toes usually were more pointed than dog toes. However, the shapes of dog toes varied enough to question any judgement based solely on this trait.

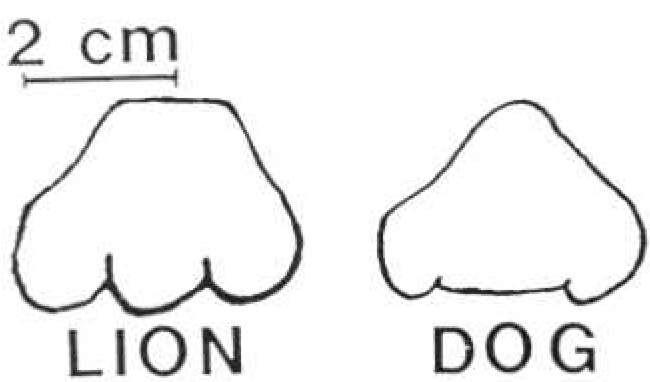


Fig. 1. Typical shapes of "heels" of dog and lion tracks. The heel lobes in lion tracks are more equal in size and shape with more distinct grooves between them.

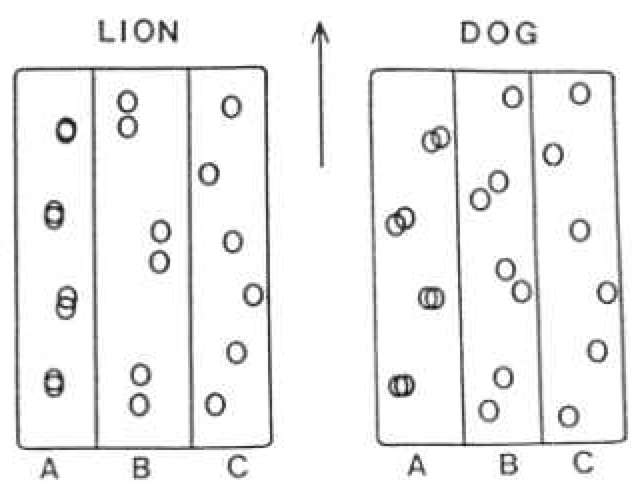


Fig. 2. Typical dog and lion track patterns that we have found in the field. The arrow in center of frames is direction of travel.

Appendix 4C

7. The common lion track pattern differed from that of dogs in several ways. Lion tracks more often occurred in pairs consisting of tracks made from the same side of the body (left with left, right with right) (Frames A and B of Figure 2) than did dog tracks. Dog tracks tended to occur more singly, usually with fairly equal distances between each track (Frame C of Fig. 2). When dog tracks occurred as pairs they usually were offset, one beside the other. Pairs of lion tracks usually included the coincidence of the rear track directly on top of the fore or directly in front of the fore. However, lion tracks sometimes occurred singly and were spaced similar to dog's tracks. Therefore, the track pattern alone is not a good track discriminator.

8. Figure 3 presents some of the dog heel pads we encountered. Although the heel pad size relative to the overall track often was similar between dogs and lions, dogs exhibited a greater variety of heel pad shapes, many of which looked quite different than lions. Therefore, many dog tracks can easily be identified based on the relative size and the shape of their heel pads, but there will always be some that look similar to the heel pads of lions.

9. We applied Belden's ratio of the widths of the widest toe to the heel pad to many dog and lion tracks and found this ratio to not work often enough to rely on it alone. A modified version of this ratio was tried in a quantitative analysis presented later in this paper.

10. A partial measure of the distance between the toes also was tried in the quantitative analysis of PART 2.

In addition, we noted several other traits that served as good discriminatory indicators, but were not found in the literature. A fairly good discriminator between lion and dog tracks was the presence or absence of a mound of soil between the toes and the heel pad. Dog tracks almost always exhibited a pronounced mound of soil, but we never saw one in a lion track. Therefore, this trait should contribute greatly to discrimination but because this mound of soil was absent in some dog tracks, it should be used with other traits as well.

We noted also that travel behavior served as a fairly good discriminator of lion and dog tracks. Dogs often wandered around the road in an almost erratic fashion with a variety of speeds, plus they stopped and started. Lions exhibited 2 main travel behaviors when on the road: they usually either traveled the route of least distance by traveling straight lines from corner to corner and then cutting the corners or they stayed to one side of the road and did not cut corners. About half of the lion track sets we encountered stayed on one side of the road. When there was heavy cover on both sides of the road, a lion exhibiting this type of behavior stayed on the uphill side of the road. But, without cover on the downhill side of the road the lion would move to this side and travel along it until cover reappeared. Therefore, travel behavior can add to the discriminatory powers of the other traits mentioned above.

The angle of the long axis of the outer toes with respect to each other also seemed to be a good discriminator. This trait was tried in the analysis of Part 2.

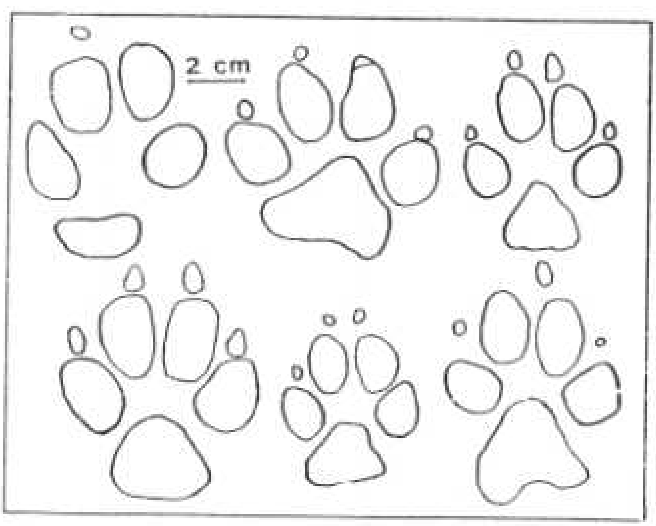


Fig. 3. An example of the variety of heel pad shapes and sizes we have seen in dog tracks. The full track is presented for reference.

Part 2: A Quantitative Analysis of Some Track Traits

Methods.

We traced the tracks of 19 different dogs and 48 different mountain lions onto acetate sheets after Panwar (1979). These tracks were used in multiple group discriminant analyses to determine which of the traits presented in Figure 4 discriminate best. Modified from Belden (1978), we used the ratio of the second toe to the heel pad (A/B). The distance between the middle toes is represented by C. The angle of the long axis of the outer toes with respect to each other was measured by first drawing a line through each of the outer toes in the direction the toes point, and then subtracting the angle E from angle D. Angles D and E were formed by the intersection of lines D and E through the base line G. The base line G w: s drawn tangent to the most posterior aspects of the ou er 2 heel lobes. F represents the average distances of

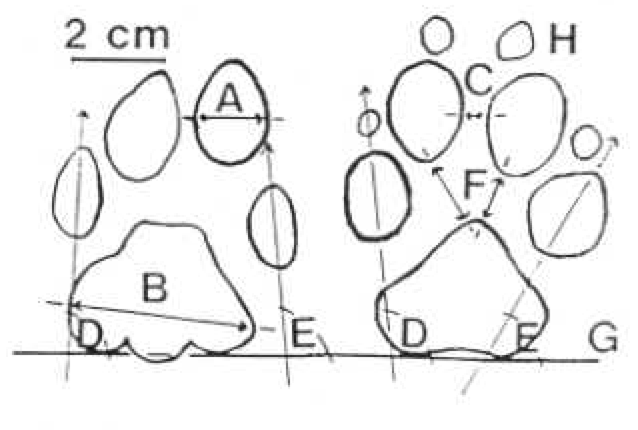


Fig. 4. Traits used in the discriminant analyses to identify dog and lion tracks.

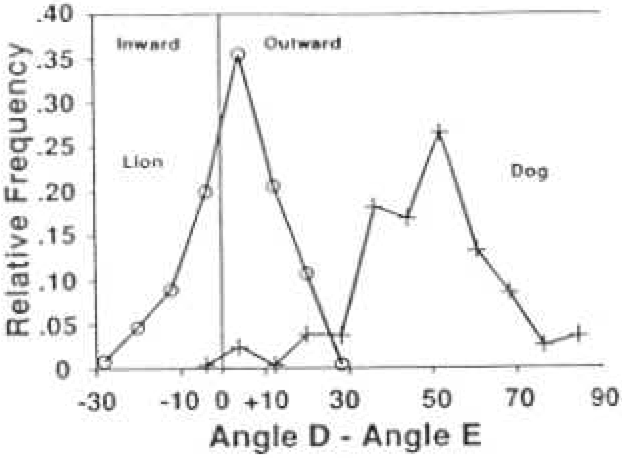


Fig. 5. Distribution of measurements for the angle of the long axis of the outer toes of mountain lions and dogs.

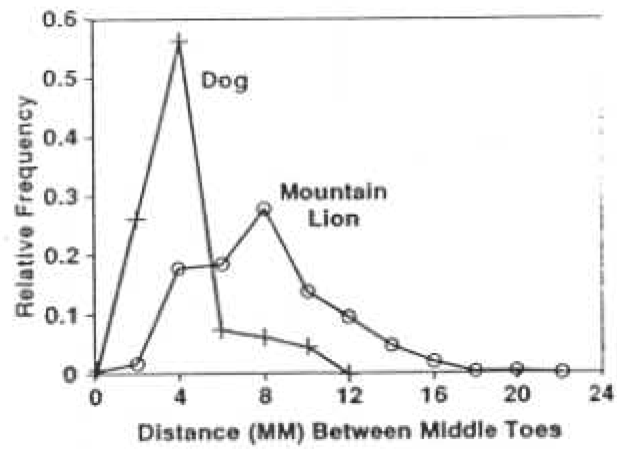


Fig. 6. Distribution of measurements for distance between middle toes of moutain lion and dogs.

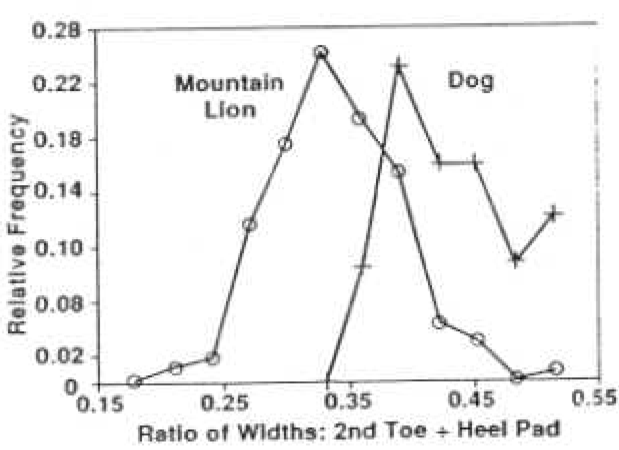


Fig. 7. Distribution of measurements for ratio of widths of second toe to the heel of mountain and dogs.

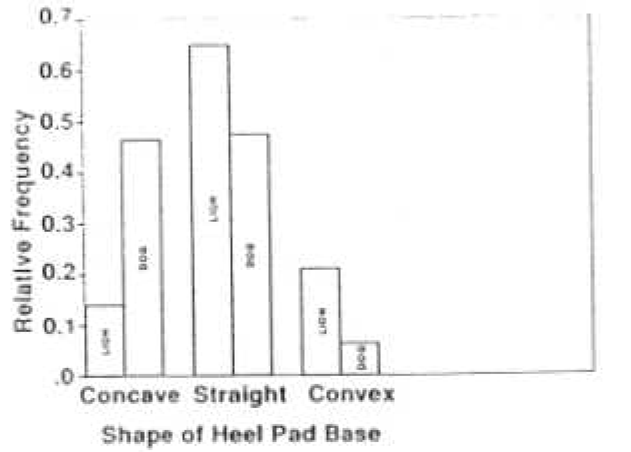


Fig. 8. Distribution of index values for shape of heel pad base of mountain lion and dogs

the middle toes from the front of the heel pad (a partial measure for the degree of track elongation). We further divided this average by the width of the heel pad B to normalize the values. H represents the presence or absence of claw marks, but was not tried in the analysis because the results were predictable. The concavity/convexity of the heel pad's posterior aspect was indexed by the degree and direction of discrepancy of the middle lobe's posterior aspect with the base line G. It could be concave [see track on the right], straight, or convex [see track on the left]). An analysis was conducted with all tracks included, one was conducted on front tracks only, and another was conducted on rear tracks only to determine if any differences exist between front and rear track discrimination. Multiple Group discriminant analysis is a statistical technique that uses known cases to develop linear combinations of variables to predict group membership of unknown cases (Norusis 1985). Figures 5, 6, 7, and 8 may help illustrate in an intuitive manner how the most discriminating combinations of variables are arrived at. The most discriminating variables best separate the two group distributions and, as variables are combined, their discriminating ability is cumulated. The effectiveness of any chosen combination of variables is determined by the proportion of known cases correctly predicted to belong to their respective groups (dog or lion). A more rigorous description of this technique is presented in a paper showing how to identify individual mountain lions by their tracks (Smallwood and Fitzhugh in preparation).

Results and Discussion

Of the traits we tried in the analysis, the angle of the long axis of the outer toes with respect to each other best discriminated dog and lion tracks and was indifferent to the front and rear track distinction (Table 1). The ratio of the widths of the second toe to the heel pad was also a good discriminator, but more so for front tracks than rear ones. The distance between the middle toes was a fair discriminator but, again, more so for the front tracks than rear. The distance between the middle toes and the heel

Appendix 4e

Table 1: Proportions of tracks correctly classified (misclassified) by different track traits from 19 dogs and 48 mountain lions in multiple group discriminant analysis.

Trait	Dog(n=63)	Lion(n=161)	Total(n=224)
	All Feet Combined		
TA	94.0 (2)	100.0 (0)	98.3 (4)
THR	74.6 (16)	92.5 (12)	87.2 (29)
ROT	58.2 (26)	79.5 (33)	73.3 (60
SOT	88.1 (7)	75.8 (39)	79.4 (46)
TA+THR	92.5 (5)	100.0 (0)	97.8 (5)
TA+THR+ROT +SOT+COP	97.0 (2)	100.0 (0)	99.1 (2)
	Front Feet Only		
	Dog(n=30)	Lion(n=69)	Total(n=99)
TA	93.3 (2)	100.0 (0)	98.0 (2)
THR	90.0 (3)	98.5 (1)	95.9 (4)
ROT	66.7 (10)	75.4 (17)	72.7 (27)
SOT	90.0 (3)	78.3 (15)	81.8 (28)
TA+THR+ROT +SOT+COP	100.0 (0)	100.0 (0)	100.0 (0)
	Rear Feet Only		
	Dog(n=33)	Lion(n=92)	Total(n=125)
TA	94.0 (2)	100.0 (0)	98.4 (2)
THR	78.8 (7)	93.5 (6)	89.6 (13)
ROT	57.6 (14)	85.0 (14)	77.6 (28)
SOT	88.0 (4)	63.0 (34)	69.6 (38)
+SOT+COP	94.0 (2)	100.0 (0)	98.4 (2)

TA = toe angles: the angle of the long axis of the outer toes with respect to each other.
THR = toe-heel-ratio: the ratio of the widths of the second toe to the heel pad.
ROT = reach of toes: the average distance of toes 2 and 3 to the front of the heel pad.
SOT = spread of toes: the distance between toes 2 and 3.
COP = concavity or shape of the posterior aspect of the heel pad.

pad discriminated lion and dog tracks fairly well for the rear tracks, but not so well for the front tracks.

The effectiveness of multiple variables in our discriminant analyses never improved enough beyond that of the angle of the long axis of the outer toes to justify the use of more variables in the field. In fact, the second toe to heel pad ratio suppressed the effectiveness of the angle of the outer toes when these were combined in an analysis.

From this exploratory analysis, we were able to consider one new discriminating variable between lion and dog tracks, as well as another derived from Belden (1978). The effectiveness of these measurements may decrease as our sample size of dog tracks increases, but the high effectiveness in this preliminary analysis is encouraging. These variables proved very useful when combining their effectiveness with some of the variables mentioned in Part I to develop the following track classification key.

Part 3: A Dog and Lion Track Classification Key

The following key is for distinguishing between dog and mountain lion tracks that are similar. Before using the key, screen out other species and obvious dog tracks. (Our smallest "adult" lion track had a heel width of 37 mm, and lions always possess 3 lobes on the rear of the heel pad.)

1. Heel pad concave at rear, two lobes . . . . . Dog
1. Heel pad with 3 lobes, shape variable 2
2. Front of heel pad squared or concave . . Mt. lion
2. Front of heel pad rounded 3
3. Claw marks present 4
3. Claw marks absent 5
4. Claws blunt . . . . Dog
4. Claws knifelike, very narrow . . . . Mt. lion
5. Angle D minus angle E = $\le 20^{\circ}$ 100% of Mt. lion + 6% of dogs 6
5. Angle D minus angle E = $\ge 21^{\circ}$ . . 94% of Dogs
6. check all interdependent factors to bring accuracy to 99%

In this key, we used the best discriminating traits identified from the discriminant analyses as well as some easy-to-recognize traits we did not need to test (or could not) in the analyses. We did not observe the knife-like claw marks that identify mountain lions in step 4 of the key, but it seems reasonable that if claw marks do appear in a lion track, they should be very thin because their claws are narrow and sharp. Field biologists can considerably increase the reliability of their track identifications if, in addition to using the key, they consider the ratio of the widths of the second toe to the heel pad, whether or not there is a leading toe, the shape of the toes, the presence or absence of a mound of soil between the heel pad and the toes, the track pattern, and the travel behavior. With discriminant analysis it may be possible to identify additional traits that discriminate dog and lion tracks well.

Acknowledgements. We thank Rob Gross and Joan Young for collecting dog tracks.

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Appendix 5a

Adrian Wydeven

CARNIVORE TRACKING FORM
Instructions

Survey Block - Write number of block.

County - List all counties in which tracking was done.

Pack Name or General Area - List pack name if known or write general area such as "Stevens Lake area".

Date - Date of survey.

Time Start - Exact time survey starts.

Time End - Exact time survey ends.

Snow Depth - Depth in inches or centimeters -- also give measurement of any new snow.

Time of Last Snow Fall - If less than 48 hours, list hours of last snowfall, otherwise list number of days.

Track Conditions -
1) Poor tracking, many prints do not register, identifications are mainly from stride and gait patterns.
2) Acceptable tracking, most prints register, but often lack detail, may need to follow into woods to identify.
3) Good tracking, every print registers but many do not show good detail.
4) Excellent tracking, every print registers and shows good detail.

Temp - Indicate temperature at start of survey.

Skies - Indicate % cloud cover.

Previous weather - High and low temperature last 24 hours and any precipitation.

Observer(s) - List all observers conducting survey.

Road Name and Direction of Travel - Start at an intersection and indicate direction you plan to travel.

Mileage - Indicate mileage at start of survey, at every identified mammal track, and at every intersection.

Carnivore Groups - Write initial for each animal under the appropriate columns.

Notes and Comments - Indicate locations of 1st observation of wolf tracks (Sec., Township, Range), indicate direction tracks travel, indicate measurements of tracks, (all wolf tracks should be measured), indicate observations of scats and raised-leg urinations (RLU's) or squat urinations (SU), indicate if any blood is observed in wolf urine; additional comments can be written on back.

Totals - Summarize total miles and total observations of each mammal; remember that if you turn around or had driven twice over any section of road, only count the mileage once; mammals that follow the road or criss-cross will be counted only once unless more than 0.3 miles occur between observations; number of wolves should be your best estimate of the number that you think you encountered based on track size, timing, and direction of travel.

Example

Appendix 6

WOLF TRACK SURVEY

Summary Sheet

Year 1996

Pack or Area Log Creek Pack, Survey Block 07

County(ies) Ashland & Sawyer

Tracker(s) John Doe

SURVEY SUMMARIES:

Date	Miles	Hours	Wolf Sign (no. tracks)	RLU's (yes or no)	Estrus Blood (yes or no)
1/10	24.0	8.0	3	Yes	Yes
1/28	28.0	7.5 hrs.	4	Yes	Yes
2/07	16.4	5.0hrs	1	No	No
2/27	32.0	7.8 hrs	4	Yes	No
TOTAL	100.4mi	28.3hrs.	12.	3/4	2/4
ESTIMATED WOLF NO. 4 wolves					

0195\SURVYSHT.AW

Appendix 5b

Example

Carnivore Tracking Form

Survey Block 07 County(ies) Achland & Sawyer
Pack Name or General Area Log Creek Pack
Date Jan 10, 1996 Time Start 0900 Time End 1500
Snow Depth 10" (2" new) Time of Last Snow Fall 20 hrs ago Track Conditions 1 2 3 4
Temp 0° - 10°F Skies (0-25) (25-50) (50-75) (75-100) Clear Previous Weather snow to 1PM yest.--cold last nite
Observer(s) John Doe and Jane Brown Sheet ___ of ___

Road Name and Direction of Travel	Mileage	*Canids	*Mustelids	*Felids	Other	Notes and Comments
Co. Hwy EE & FR161 going N.	10.0					Start survey
FR161	12.1		1F			
"	13.5	1F				
"	14.2		1F			
"	15.0	3W				came from W and headed N on FR161; Section 11 T40N, R3W
19.2 "	15.5			1B		4½"x4"; 4¼"x3¾"; 4"x3½"
"	15.9		1,0			
"	16.7					wolves went to NE -- 4 RLUs from 15.0-16.7
FR161 + FR162 going S.	17.9					
FR162	18.5		1F			
"	19.2	1F				
"	20.2		1F			
"	23.0	2C				
FR161 + Hwy 70 Turnaround	24.2					Going back N. to intersection FR161 & FR162
Intersection FR161 + FR162 going N.	29.5					
FR162	30.6		1F			
"	31.8	1F				
9.8 Inters. FR162 + FR163 going NE	32.1					
FR163	33.0	3W				Came down FR163 from E
"	33.2					2 RLU's & 1 scat
"	34.1					1 RLU with blood in urine
"	34.3					wolves came from S.
"	35.0			1B		
"	35.8		1F			
Inters. FR163 + FR164 going E	37.2					
FR163 (Bear Lk Rd.)	39.3					Hay-field to south - End survey
TOTALS	24.0	3W 2C 3F	6F 1 otter	2B		

* Canids: C = Coyote, D = Dog, F = Fox, W = Wolf
Mustelids: F = Fisher, M = Marten, MK = Mink, O = Otter, S = Skunk, W = Weasel
Felids: B = Bobcat, C = Cat, L = Lynx, P = Puma
Other: B = Bear, BV = Beaver, P = Porcupine, R = Racoon